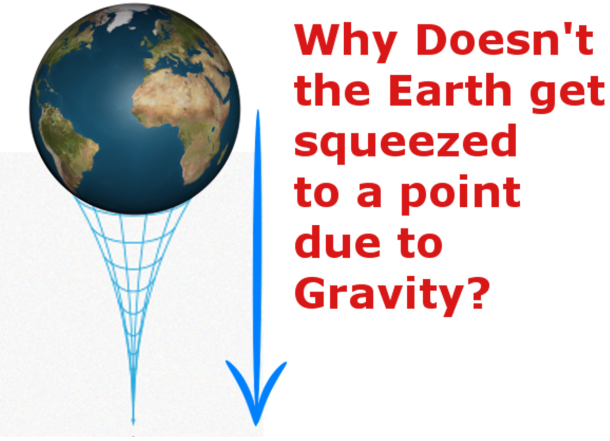
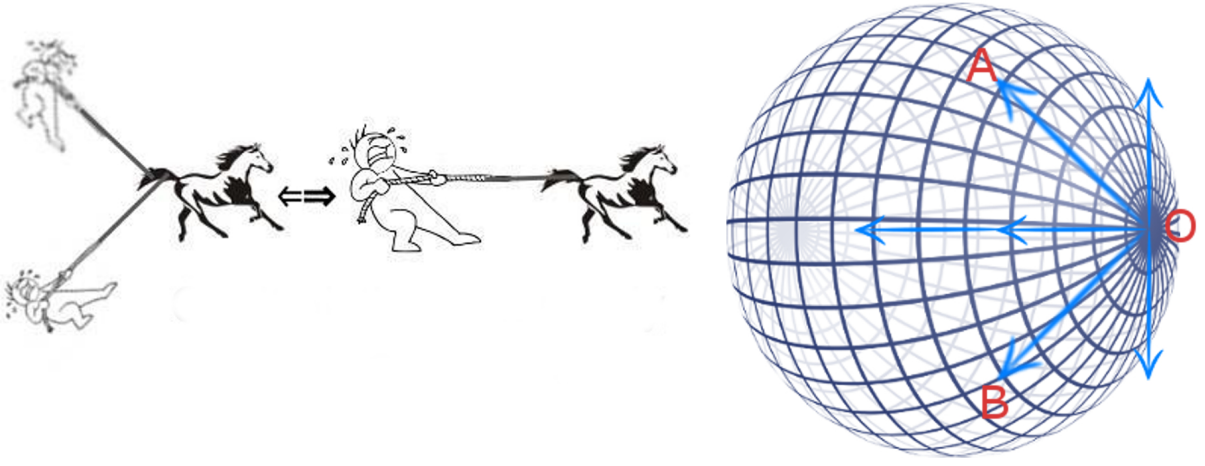
Forces other than gravity



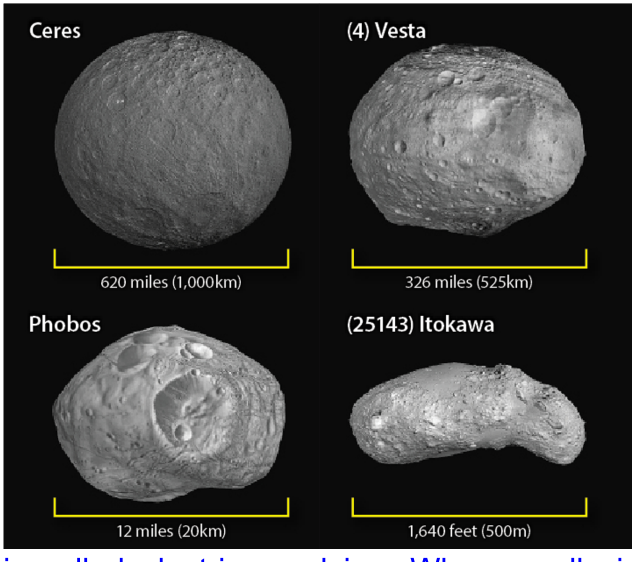
Why are the earth, the sun, the moon and other planets spheres? Force of gravity must exist between every pair of small parts of these spheres. Then what keeps them separated? For that matter, why don't all the parts of the earth collapse into the center? {Picture left} Hills and boulders are found in different shapes. Is there no force of gravity between parts of these? When we seek answers to these questions, we realize that there must be forces other than gravity in nature.

In the earlier example of two people trying to stop a runaway horse, {Picture top left opposite page}, a part of the force they exerted was in the direction opposite to that of the running horse. This obviously means that the force exerted by the horse is being divided into two parts, in the direction of the two ropes. Similarly we can divide the gravitational force between any two minute parts of a sphere into two parts, one towards the center of the sphere and another, perpendicular to this on the surface of the sphere. {Picture top right opposite page} All the mass appears to be concentrated at the center because all the forces between every pair of small particles in the sphere, in the direction of the center are getting added. So calculations made by assuming simply that all mass is at the center agree with experiments. Now the parts of the force along the surface are left. Because the sphere is symmetrical, the total surface force will be zero. As shown in the picture, for every pair of small particles, there is a mirror image pair. The surface forces due to these



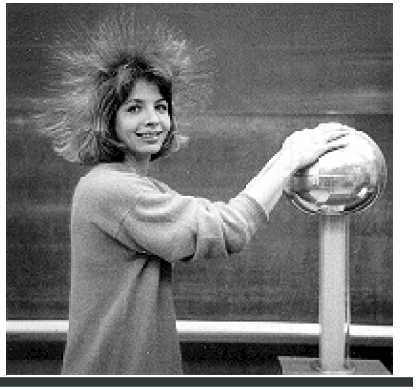
two pairs are equal and opposite. The net force is zero just as when the two people trying to stop the horse are directly opposite to each other. But this symmetry is seen only in a sphere. If the shape is not a sphere and surface forces are not zero, So, Newton's law demands that the parts of the body move. Planets and stars are very heavy, so their gravitational forces are extremely large. So the finite particles would keep moving till the surface force is zero, that is till the planet or star becomes a sphere.

The stars appear to be points without any visible size of diameter. But scientists successfully measured the diameters of thousands of nearby stars and proved that they are spheres. Asteroid Ceres looks perfectly spherical and its diameter is one fourth that of the moon. {Picture next page} Vesta, half the size of Ceres, is a deformed sphere. Phobos, another astronomical object with a maximum size of 20km, does not look spherical at all.

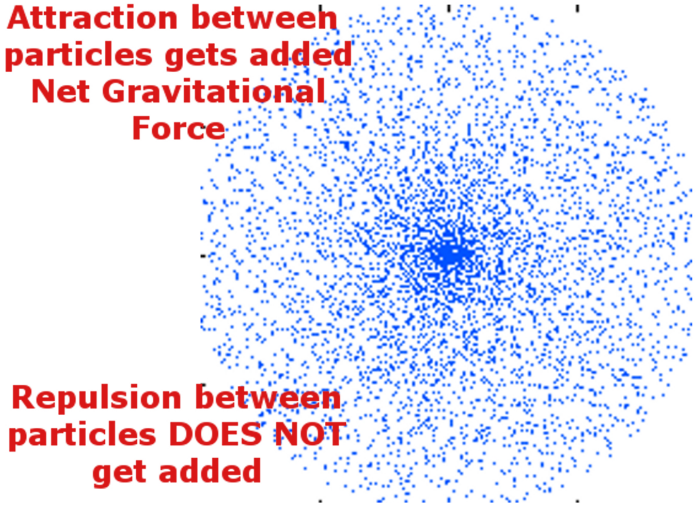


Itokawa, which is only 0.5 km long looks like a very large peanut. {Picture left} As the asteroids become smaller their gravitational force becomes smaller and they look less like spheres. Clearly, all solid materials do have a force that resists the movement of the small parts. Large asteroids and the planets have large enough gravitational force which overcomes this resistance and they become spheres. The very same force obviously resists the movement of all parts to the center.

One force of repulsion between material bodies has been known for a long time. This is called electric repulsion. When small pieces of amber are rubbed with wool, they repel each other. To make a more dramatic demonstration, human beings can be connected to a source of electric charge. {Picture right} The individual hairs stand up and repel each other. The same force opposes gravity in astronomical objects.



Small material particles come together due to the force of gravity and eventually form stars and planets. {Picture top left opposite page} This takes enormous time. But different



stages of this process have been observed in space. Planets and asteroids in the solar system are visible only because they reflect sunlight. But when they were being formed, the gravitational force of attraction performed work against electric repulsion. This work done becomes the potential energy of the bodies which then gets converted to heat. Scientists estimate that during formation, the temperature of the big planets could have been 100000^{o}C or even more. As they lost the heat energy into space, they cooled and are no longer visible except when they reflect sunlight. Experiments reveal that even now, the temperature at the center of the earth is several thousand degrees centigrade.

There is a very important difference between the forces of gravity and electrical repulsion. The gravitational forces due to the large number of small particles get added. The electrical forces of repulsion between them do not get added. The force of electric repulsion does not increase with the size of the object. In the sun and other stars, the gravitational force is too large for the force of electric repulsion to resist gravity and maintain a spherical shape. Ceres with a mass six thousandth of the mass of the earth and Jupiter three hundred times

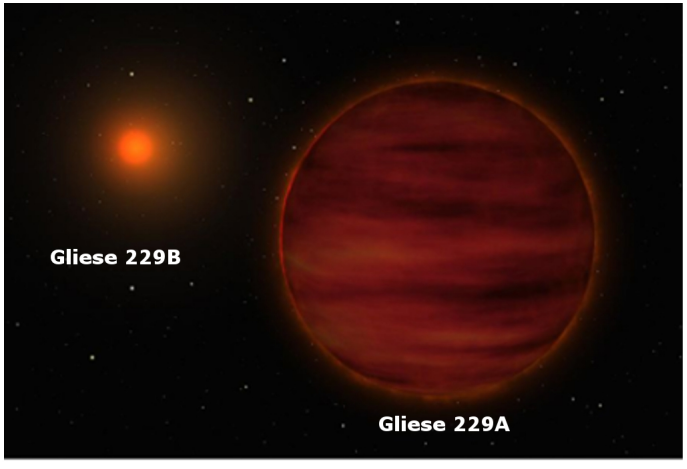
Ceres
1/6000
Mass of earth

Earth

Jupiter
300 times
Mass of earth

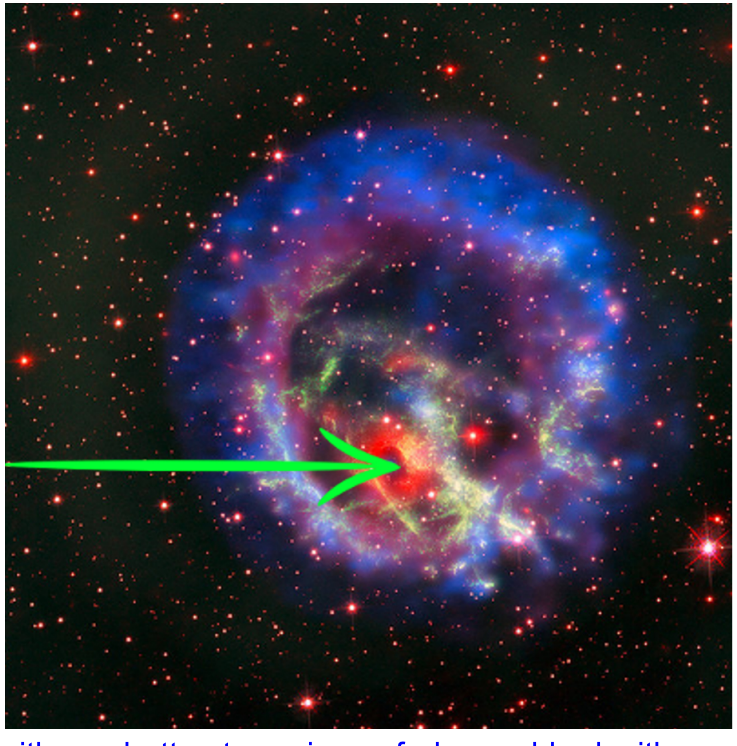
heavier than earth are in stable spherical shapes because the electric repulsion balances gravity. {Picture above} Those masses are the limits to this stability. Electric repulsion is the second force of nature we encountered.

As gravity overcomes electric repulsion and moves the particles of matter closer together, the temperature increases beyond a million degrees. At that point, two other forces of nature come into play. They convert matter into energy. This resists the force of gravity and also makes the stars self luminous. So far as we know, {Picture top left opposite page} Gliese A is the smallest self luminous star. It's mass is about one tenth the mass of the sun. It's twin star Gliese B is half as heavy as the sun. The sun converts roughly four million tons of matter into energy. {Picture top right opposite page} This has been going on for some five billion years and scientists estimate it will continue for another five billion



years. All stars are born when clouds of matter in outer space called nebulae condense due to the force of gravity. Some stars die in huge explosions. Matter thrown out into space by these explosions forms new stars. Parts from ancient star explosions are present in the sun, the planets of the solar system and even human bodies.

Some stars are dim and shine forever. Others shine bright but for a shorter time. These stars explode. After the explosion some cool down. Some others turn into a peculiar form of matter called a neutron star. {Picture on next page} Some others become backhoes from which even light cannot escape. Their presence is only known from the gravitational force they exert on other bodies. The mass at the time of formation determines how the star glows and what it becomes. Stars which have mass more than twenty times the mass of the sun become blackholes.



Physics explains all these complex and very surprising observations by proposing that there are two more forces of nature other than gravity and electric repulsion. These are not required to explain day to day life. Physicists use these forces only to explain a few physics experiments, generation of atomic power, atomic bombs and radioactivity. Explaining these forces without first describing quantum mechanics is very very difficult. So these are not discussed any further in this book.

Electrical attraction was observed along with electric repulsion. Just like amber, two small pieces of glass repel each other when rubbed with wool. But a piece of amber rubbed with wool attracts a piece of glass rubbed with wool. Both amber and glass when rubbed with wool attract feathers and small pieces of paper. A dramatic presentation is the cat fur attracting small pieces of Styrofoam {Picture opposite page} Just like electric repulsion, electric attraction does not increase with the size of the object. The gravitational force between two small objects is very small and can be ignored in practice. So, the forces of

Styrofoam peanuts cling to cat's fur
Electrostatic force of attraction

electric attraction and repulsion are sufficient to explain almost all the properties of small objects. If the experimental results are very accurate and have to be compared with calculations, once again quantum mechanics is needed. But quite a lot can be understood even with ordinary language.

One important issue. Some people claim. "Einstein proved Newton was wrong". Often, this argument is used to claim that contemporary science could also be eventually proved wrong and claims of their own cultural texts justified. But this claim is stupid. Einstein showed that when the speed of a body becomes comparable with the speed of light, some corrections are required for Newton's physics. When the speed of an object is much smaller than the speed of light, the calculations of Einstein and Newton are identical.